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Orotaxial Geologic Correlation and Diastrophism

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OROTAXIAL GEOLOGIC CORRELATION AND DIASTROPHISM.

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Exact stratigraphic correlation is today bothering the geologist more than any other subject relating to earth knowledge. This phase of geology has, indeed, been a constant source of embarrassment ever since the science's birth more than a century and a half ago. A hundred years ago William Smith, an English engineer, discovered the use of organic remains in the determination of the relative ages of rocks; and since his time fossils have been very generally depended upon in unravelling the geologic history of the various parts of the globe.

During the last quarter of the last century stratigraphy began to demand quantitative, instead of merely qualitative, results. Other stratal criteria of a critical character were found to be, in the field, of even greater practical value than the fossils could ever hope for. At the present time most of the geological surveys have adopted a lithologic standard for the geologic unit in mapping; and the fossils come to have only a secondary importance, or are ignored altogether. Even this scheme has not proved to be so satisfactory as was anticipated. It is now quite manifest that we shall have to seek more fundamental criteria in the interests of exact geologic correlation. We shall have to look more carefully into the factors which control sedimentation, which modify it, and which delimit the geologic terranes.

Every classification of natural objects is very simple and very perfect so long as we make no comparisons with other methods and do not adopt any other criteria. For example, we may classify plants by means of their flowers; or by their leaves. We may arrange systematically the mammals according to their teeth. So, also, we may construct an elaborate stratigraphic scheme in accordance with the contained fossils and have, to all appearances, not only a complete but a seemingly flawless plan. This for the last hundred years the paleontologist has tried to impress upon us. It is, however, a classification of organic remains and not necessarily of geologic formations.

When we make comparisons with other standards, which seem equally critical, the shortcomings of the paleontologic method become alarmingly glaring. When closely examined the paleontologic scheme of geologic classification is found to be not a classification of terranes at all, nor a logical arrangement of historic events, but merely a rather imperfect grouping of faunas. The question arises whether in stratigraphy we should not be better off today if we were to ignore the fossils altogether, or recognize them only in the most general way.

At the meetings last winter in Baltimore of the American Association for the Advancement of Science, and of the Geological Society of America, there was

a notable symposium on geologic correlation occupying the time for several days. This fact alone is indicative of the great interest which is being taken in the subject at the present time. The most suggestive paper of all, perhaps, was the one presented by Professor Chamberlain, of the Chicago University. In it was urged the use of diastrophism as an ultimate basis of geologic correlation. This is essentially the utilization of the expressions of the local changes in elevation or depression of the surface of the globe, particularly along the sea-coast, due to mountain-making and epeirogenic movements.

Now, it may be of no little interest at this time to recall the fact that eleven years ago there was read before this Academy a paper* on this very subject. It was entitled "Some Physical Aspects of General Geologic Correlation." This paper was a more mature consideration of an article published in the *American Geologist* three years before†, and called "Orotaxis: A Method of Geologic Correlation." Since that date I have referred on several occasions specifically to the subject‡, particularly in treatings§ of the "Orotaxial Significance of Certain Unconformities."

As originally stated** the definition of orotaxis, or stratigraphic correlation upon the basis of diastatic, or diastrophic, movements is essentially as follows: "The immediate causes for the changes between the relations of the land and sea areas are to be sought in orogenic and epeirogenic movements. As the two kinds of movements cannot be readily separated practically, and as it is of small advantage to separate them theoretically, the results produced may be all regarded as arising from the one cause—that is, from mountain-making forces. The greatest and most abrupt modification in sedimentation, and consequently in lithologic, faunal, and, in fact, all characters, are those connected directly with diastatic change, producing depression of some land areas below sea-level, and the uprising of other districts above the level at which they once stood, to form those great features of the earth's surface called mountains. Geologic chronology, therefore, is believed to find a true and rational basis in those changes which primarily govern sedimentation and which are intimately connected with the genesis of mountain systems. It is proposed, therefore, to emphasize this factor as fundamental in the marking out of the leading subdivisions of geologic time and to define general stratigraphic succession in accordance with the cycles of orogenic development, calling the classification, or the fundamental principle of correlation, a systematic arrangement of mountains, or orotaxis."

By the term mountains is meant not alone those geographic features which at the present time rise so majestically and conspicuously above the earth's surface, but also all of those remnantal structures which have been in the past prominent characters in the surface relief and which, geotectonically at least, are still mountains, though perhaps now completely planed off and buried beneath later sediments. With these old mountains the cycles of orogenic deveopment are properly regarded as extending from the time when the strata first were flexed, through the periods when they were bowed up, then planed off nearly to sea-level, and submerged, perhaps, until new degredational products

*Proc. Iowa Acad. Sci., Vol. VI, pp. 131-154, 1899.

†American Geologist, Vol. XVIII, pp. 289-303, 1896.

‡See; Science, N. S., Vol. XII, p. 146, 1900; also, Bull. Geol. Soc. America, Vol. XII, p. 175, 1901.

§Am. Jour. Sci. (4), Vol. XXI, pp. 296-300, 1906.

**American Geologist, Vol. XVIII, p. 298, 1896.

were deposited upon their upturned edges. The completed cycle of mountain-making is the measure of orotaxial chronology. The division-planes cutting the geological column into series, terranes and the smaller subdivisions are actually, as well as theoretically, the lines of unconformities and their representatives. In the cases of the more extensive features of discordant sedimentation they represent no doubt base-leveled surfaces, or peneplains.

As a concrete illustration there is probably no better one than that presented by the stratigraphy of the southern end of the Rocky mountains. There are in the geologic column more than a score of well defined terranes having the taxonomic rank of series. With possibly one or two exceptions they are all separated from one another by marked planes of unconformity. The most exact means of correlation over wide areas are given. Of not the least interest are the comparisons that are able to be made with the geologic sections both to the eastward in the Mississippi valley and to the westward in the Great Basin region.

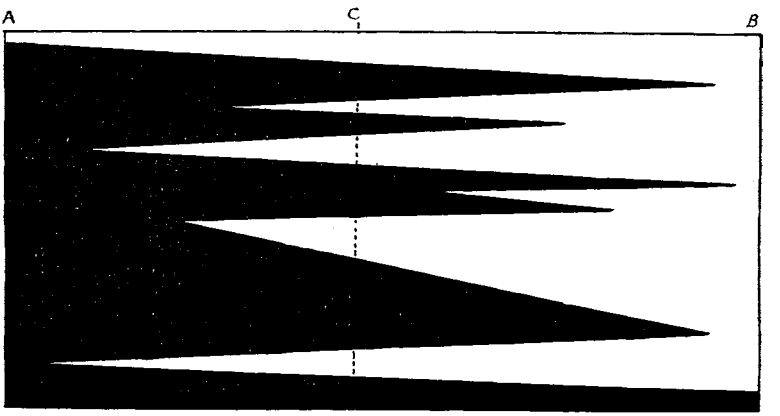

Figure 1. Oscillation of Continental Shore Lines.

In the domain of geologic correlation the most important deduction of recent years is that there is an erosional history of continental borders equally significant as that expressed in the sedimentary record. At best the sediments present only one-half of the stratigraphic history. The historical testimony of the fossils is not only fragmentary so far as the sediments in which they occur are concerned but it gives no suggestion of the erosional sequence of events which are of even greater consequence.

If we represent in diagram (Fig. 1) an ideal cross-section of a continental border, complete sedimental history stands at one side (section A), and complete erosional history at the other side (section C). In terms of the sediments the latter is an hiatus, or as the older text-books on geology call it a time-gap. The section B represents about as much of the complete history as the fossils ordinarily record. In reality the history which organic remains portray is merely that of faunal sequence, with no necessary relationships of physical episodes suggested; in its entirety it is only a small and imperfect fragment of the actual record of geologic events.

The zig-zag line may be further taken as indicating the oscillations of a shore-line; and also the course of the migration of a specific fauna during geolo-

gic time. At B, where the biologic section is made the point of special inquiry, the recurrence of faunas is graphically explained. More important than this is the weakness of the biotic method of geologic correlation that is shown; and the great strength and exactness of the correlative methods which are purely physical in character that are indicated.

The sedimentative section with its contained fossils stands for the continuous record; while the erosive history represents the rhythmic breaks which make possible exact correlation of terranes and general stratigraphic classification. The stratigraphic expression of the latter is the unconformity. This again is the outcome of diastatic, or diastrophic, movements, or more impressively and more readily recognizable in the field, the results of mountain-making changes upon the position of the shore-line of the ocean. Systematic arrangement of terranes on this basis is fundamental; it is strictly genetic; it is not dependent upon the often more or less fanciful interpretation of fossils; it is directly in harmony with the laws controlling sedimentation inself; it is the most practical and exact of any method yet devised; and it enables the votaries of geologic correlation to swing entirely clear of paleontology.

The nicety and rapidity with which the orotaxial principles act in practice are indicated by a number of concrete examples. In the Upper Mississippi valley the values of the different methods of geologic correlation have been recently specifically compared.*

In the Ozark region the shortcomings of the older methods of geologic classification have been pointed out.† Around the southern end of the Rocky mountains, in central New Mexico, the great value of the orotaxial method has been especially emphasized.‡ Its value has been determined in the unfossiliferous Tertiary deposits of the Death Valley region in eastern California and Nevada.§ Earlier Irving** strictly followed the method in correlating the Pre-Cambrian sequence of the Lake Superior region; and McGee†† applied its principles to the unfossiliferous formations of the Atlantic Coastal plain.

In the present advanced state of stratigraphical science, in which reconnaisance work is no longer needful over the large part of our country, it seems that we have reached a stage where classification of terranes should follow definite principles in accordance with the taxonomic ranks of the various geologic units, much in the same way that it is accomplished in botany or zoology. A dual geologic classification—one structural and the other biotic—is certainly superfluous. The biotic scheme may be advantageously eliminated entirely as it is now really done in practice by all except the old-school paleontologists.

We may arbitrarily recognize the larger divisions as worldwide time-divisions; and regard the sediments as deposited during certain eras or periods. The latter may also be advantageously subdivided into Early, Mid and Late classes, still retaining the time criterion. Below the taxonomic rank of period, or sub-period, however, geologic sections are provincial in character. The structure sequence of the region now becomes the most critical of the corre-

*Proc. Iowa Acad. Sci., Vol. X, pp. 105-107, 1903.

†Bull. Geol. Soc. America, Vol. XII, pp. 173-196, 1901; also, Ibid., Vol. XIII, pp. 267-292, 1902.

‡Am. Jour. Sci. (4), Vol. XXI, pp. 296-300, 1906.

§Trans. American Inst. Mining Eng., Bull. No. 34, pp. 867-903, 1909.

**U. S. Geol. Surv., 7th Ann. Rept., pp. 437-439, 1888.

††Cong. geol. international, 5me Sess., p. 164, 1903.

lative criteria. The series is all-important and not its time equivalent, which begins to have very vague definition even when different parts of the same geologic province are compared; and necessarily so in provinces with dissimilar histories. This plan gives prominence to the structural unit of geologic mapping, the lithologic formation, or terrane. Minor subdivisions of the latter may be delimited by the specific mineral peculiarities of the fossils.

By clearly distinguishing between geologic history and biotic history geologic correlation is placed upon a rational, genetic and philosophic foundation. Stratigraphy is immeasureably advanced.